

# Participation in Science and Technology: Young people's achievement-related choices in late modern societies

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## Abstract

Young people's participation in science, technology, engineering, and mathematics (STEM) is a matter of international concern. Studies and careers that require physical sciences and advanced mathematics are most affected by the problem, and women in particular are under-represented in many STEM fields. This article views international research about young people's relationships to and participation in STEM subjects and careers, through the lens of an expectancy-value model of achievement-related choices (Eccles et al., 1983). In addition, it draws on sociological theories of late modernity and identity which situate decision-making in a cultural context. The article examines how these frameworks are useful in explaining the decisions of young people – and young women in particular – about participating in STEM, and proposes possible strategies for removing barriers to participation.

## Keywords

Participation, STEM, educational choice, gender, expectancy-value model, modernity

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## 1 Introduction

A key theme running through much of the recent science education literature has been the increasing reluctance of young people in many parts of the world to participate in science, technology, engineering and mathematics (STEM). Awareness of this disinclination emerged in the early 1990s with several national reports identifying shortages of science graduates and declines in student interest in school science. As the number of such reports grew, international comparative studies were undertaken to investigate the extent of these trends. The commonalities revealed by these studies across a number of countries have led research in this field to the point where broader explanatory models are now needed to account for the fact that the trend appears to be more closely associated with socio-cultural characteristics of a generation than with national economies or education systems.

This article examines international research about young people's relationships to and participation in STEM subjects through the lens of a contemporary model of achievement-related choices (Eccles, et al., 1983; Eccles & Wigfield, 2002). While the article is structured primarily around features of the Eccles et al. model, it also draws on sociological theories of late modernity and identity which situate decision-making in a cultural context. The article examines how these frameworks are useful in explaining the decisions of young people - and young women in particular - about participating in STEM, and proposes possible strategies for removing barriers to participation.

### 1.1 The nature and scope of STEM participation problems

One challenge in examining such a multidimensional issue is the difficulty of establishing parameters and internationally comparable terms of reference. In framing the problem, at least four interrelated dimensions need to be considered: the range of STEM subjects; the different national contexts; the different critical decisions points, and the patterns of participation among young men and women.

In terms of the first of these, it is recognised that the so-called 'STEM problem', does not apply equally to all STEM fields or their component disciplines. For instance, university enrolments in life/health sciences such as medicine, biology and biochemistry are considered sufficient to meet projected demand in most developed countries (Organisation for Economic Co-operation and Development [OECD], 2008), while supply and demand of ICT graduates have fluctuated wildly over the last decade or so (OECD, 2010b). On the other hand there are predictions of widespread shortages in most engineering disciplines (United Nations Educational, Scientific, and Cultural Organization [UNESCO], 2010), and many OECD countries report serious under-enrolments in university physics, mathematics and, to a lesser extent, chemistry courses.

It should be noted that such projections of supply and demand are complicated by the economic impact of the Global Financial Crisis (GFC), which not only dampened demand for a wide range of STEM graduates but affected university enrolment patterns in complex and unpredictable ways (see for example Institute for International Education [IIE], 2010; Paton, 2010; Sursock & Smidt, 2010). Nevertheless key economic organisations predict a gradual global recovery over the next year or so (International Monetary Fund [IMF], 2010; OECD, 2010a), and in view of the long term trends prior to the GFC documenting an undersupply of STEM graduates in many countries, it is entirely possible that following this recovery the general trends of STEM participation over the last two decades will continue where they left off. Certainly there is no indication that the gender disparities in some STEM fields discussed below will be reduced in the wake of the GFC.

It is apparent from the discussion above that in the context of supply and demand trends, STEM is a somewhat generic and ill-fitting term. Nevertheless, given its broad acceptance in the literature it is the most convenient - or perhaps the least inconvenient – shorthand term available for discussing the complex cross-discipline issues addressed in this article.

Consideration of the second dimension – different national contexts - reveals variations within the trends outlined above. First and foremost, young people's increasing reluctance to participate in physical science and mathematics subjects has been most evident in highly developed and modernised parts of the world such as Europe (European Round Table of Industrialists [ERT], 2009; OECD, 2008), the US (Stine & Matthews, 2009), Australia (Lyons & Quinn, 2010), New Zealand (Hipkins & Bolstad, 2005a), Canada (Government of Canada, 2007), Japan (OECD, 2007b; Ogura, 2005) and Korea (Anderson, Chiu, & Yore, 2010). By contrast, research indicates that there is a greater enthusiasm for science and technology careers among young people in less developed countries (Sjøberg & Schreiner, 2010). It is also likely that many less developed nations will continue to experience lower unmet demand for scientists and technicians than developed or emerging countries (Qurashi, Kazi, & Hussain, 2010). Hence this article is limited to discussion about STEM supply and demand in highly developed countries.

Even within this group, the nature and extent of the problems vary with national demographics, labour markets and education systems. For instance, engineering graduates are in greatest demand in Australia, Germany, the US, Canada, Norway, the UK and New Zealand (Kaspura, 2010; Manpower, 2009), while serious shortages of physics and chemistry teachers have been reported in the UK, Norway, Denmark, the Netherlands (Osborne & Dillon, 2008) the US (Hodapp, Hehn, & Hei, 2009) and Australia (Department of Education, Science and Training [DEST], 2006). There is also contention about the scale and nature of reported shortages, particularly in the US where some researchers have questioned whether calls for increased supply of STEM graduates such as *Rising Above the Gathering Storm* (US National Academies, 2007) are misplaced (Lowell, Salzman, Bernstein, & Henderson, 2009).

A third dimension differentiates the critical points in students' lives when decisions are made about participating in STEM subjects or careers. Notwithstanding the evidence that students' conceptions and attitudes evolve gradually and from an early age (Osborne, Simon, & Tytler, 2009), this dimension is also punctuated with formal opportunities - transition points - in secondary and tertiary education. Again, these points vary with the type of education system. In many countries students make their first decision about taking non-compulsory subjects around the age of 15-16 years. Experiences of junior high school science can therefore have a significant influence, since decisions to forgo science subjects generally put an end to any formal science education.

There is substantial evidence that young people have been disengaging from science at this first decision point. In the UK for instance, the proportion of students taking A-level physics fell from 6.6% to 3.4% between 1990 and 2008, a decline of 49%. The proportion taking chemistry fell from 6.8% to 5%, a decline of 26% (Joint Council for Qualifications [JCQ], 2009). Over the last two years both subjects have registered increases, with 3.8% and 5.2% of A-Level entrants in 2010 taking physics and chemistry respectively (JCQ, 2010). While an encouraging sign, it remains to be seen whether this upward trend will be sustained.

In Australia, proportionally fewer students have been choosing science at the first decision point. According to Ainley, Kos and Nicholas (2008), between 1992 and 2007 the proportions of senior high school students taking physics, chemistry and biology courses declined by 26%, 22% and 29% respectively. More recent figures suggest a stabilisation rather than an upturn as in the UK (Lyons & Quinn, 2010). Researchers in New Zealand have also reported early student disengagement from science and mathematics (Hipkins & Bolstad, 2005b). In many countries, increased student disengagement from STEM has been most apparent in the secondary tertiary transition. In France for example, the percentage of high school graduates enrolling in first year university science courses (excluding health and medicine) almost halved from 8.4% in 1995 to 4.3% in 2007 (Arnoux, Duverney, & Holton, 2009). Over the last decade universities in Japan have been increasingly concerned about *rieki banare* or the 'flight from science'. The number of students studying science and engineering at university decreased by 10% between 1999 and 2007 (Fackler, 2008).

A fourth categorical dimension is gender. There is clear evidence that young men and women in different countries tend to make different choices about STEM participation. For example, the 2006 PISA study reported that in Japan, Korea, the Netherlands, Germany, Iceland and Taiwan 15 year old boys were significantly more inclined towards future science-related study and careers than were girls. In contrast, results from Sweden, Denmark, Australia, New Zealand and Canada showed little difference in the intentions of boys and girls (OECD, 2007b). In terms of specific STEM subjects, however, young women at school and university tend to be underrepresented in physics, engineering, mathematics and technology subjects, and overrepresented in the life and health sciences (Dobson, 2007; EU, 2006, 2009; NSB, 2010; National Science Foundation [NSF], 2006). This gender disparity is reflected in career profiles in these fields.

This situation motivates the specific focus we have on gender in this article, and underscores the particular challenge in recruiting more young women to STEM. Exploring the different influences on young men and women is a classic element of studies in science and mathematics education (see e.g. Eccles, 2007; Jenkins, 2006; Kjærnsli, Lie, Olsen, & Roe, 2007; OECD, 2007a; Osborne, et al., 2009; Scantlebury & Baker, 2007; Schreiner, 2006; Sørensen, 2007), with much research addressing gender issues and approaches to gender equity in science and mathematics education (for reviews see Hutchinson, Stagg, & Bentley, 2009; Kenway & Gough, 1998; Spelke, 2005). The observed gender differences in STEM participation are by no means new, and have generated debate for several decades. One central issue in such debates is whether or not these differences, so persistent over time, spring from genetic differences, for instance in mathematical aptitude, between young men and women. However, evidence indicates that socio-cultural factors and constraints constitute the most powerful explanatory factor behind women's underrepresentation (Ceci, Williams, & Barnett, 2009), and that to the extent that gender differences in mathematics and science achievement are observed, they are small in effect size and often represent an overlap of around 90% in the score distributions of young women and men (Hyde & Linn, 2006).

While acknowledging the interrelationships between and differences within the four dimensions above, this article addresses at its core young people aged 15-20 years from highly developed countries and their relationship with, and aspirations towards subjects and careers requiring physical science and advanced mathematics. Within this scope the article has a particular focus on the deliberations of young women.

## 1.2 Five reasons for why participation in STEM is important

The previous section documented how the STEM participation situation is cause for concern. However, we believe that there is more to this issue than simple "supply and demand" considerations. We will present five reasons why more people in general, and more women in particular, should participate in STEM education and careers.

1. Society needs more people in STEM professions in order to fill current and future demands, for instance, to secure a sufficient and sustainable energy supply, responsible resource use, efficient health care in all parts of the world, clever technology development, and a sound economy.
2. STEM needs a greater diversity of professionals (more women in particular) in order to develop in new ways (Schiebinger, 2008). A greater diversity of experiences, perspectives, and work forms among professionals may increase the innovative potential and propel STEM forward, helping it adapt to rapidly changing societies and to the diverse purposes and applications of STEM around the world.
3. Women and other under-represented groups need STEM to be empowered to influence their own lives and the development of the world. These groups should be encouraged to participate with their priorities on the arenas where decisions are made concerning research and technology development. A classical example concerns women's health, which has received increasing focus in medical research as a result of women's engagement (NIH, 1999). Another aspect of this argument is that the failure of women to pursue STEM careers limits their career opportunities and earning potential. To sum up; involvement in STEM gives people literacy, empowerment and economic freedom to shape their world and everyday life.
4. Everyone should be given the chance to engage in the wonders of the scientific and technological world, which may enrich their lives and contribute to their individual development. This is in line with the ideals for a liberal education as described for instance by Carson (2002).
5. Everyone should have a real, not only a formal, free choice of education. The norms, stereotypes and expectations young people meet should allow for a role for women and other under-represented groups in STEM. Stereotypical views of scientists are still prevalent and fit poorly with the ideals that are held up, particularly for young women, by contemporary culture. Young people will not have a real free choice of education before these mental and cultural barriers are reduced.

## 1.3 Approaches to understanding the problem

The nature of young people's educational decision-making is complex, and many approaches can and have been taken to understand their choices. In psychology, theorists have, for example, linked educational choices to individuals' personality types (Costa, McCrae, & Holland, 1984; Head & Ramsden, 1990). In sociology, educational and vocational behaviour have been understood as products of socio-economic factors such as social class (Ball, Davies, David, & Reay, 2002; Bourdieu & Passeron, 1990). Less polarised approaches to academic motivation include *self-efficacy* theory (Bandura, 1997), *intrinsic and extrinsic motivation* (Ryan & Deci, 2000), *interest development* (Hidi & Renninger, 2006; Krapp, 2005), *attribution theory* (Weiner, 1985), and *expectancy-value theory* (Eccles, et al., 1983).

### 1.4 The Eccles et al. expectancy-value model of achievement-related choices: A clarifying lens

The Eccles et al. expectancy-value model of achievement-related choices (Eccles, et al., 1983)(Figure 1) is comprehensive and based on empirical evidence. It is founded in social psychology, and incorporates social, psychological and cultural aspects that have been shown to affect young people’s motivational behaviour. Important components of the model are the expectations and values of individuals concerning their choices about participating in an activity. Eccles and her colleagues have developed and tested this model over many years and in many studies (Eccles, 2009; Eccles, et al., 1983; Eccles, Barber, & Jozefowicz, 1999; Meece, Wigfield, & Eccles, 1990; Nagy et al., 2008). The model has for example contributed to the understanding of how achievement is linked to interests and self concepts in mathematics, language and science (Denissen, Zarrett, & Eccles, 2007), of college enrolment in mathematics and English (Eccles, Vida, & Barber, 2004) and high school course enrolment in mathematics and science (Simpkins, Davis-Kean, & Eccles, 2006), and of links between interest and competence in sports (Fredricks & Eccles, 2002). A specific focus on gender is often seen, for example in studies of women’s educational and occupational choices in relation to physical sciences, engineering and applied mathematics (Eccles, 1994; Eccles, et al., 1999). The model is inclusive in the sense that many of its constructs overlap with concepts from other motivational theories. These include Bandura’s (1997) *self-efficacy*, Ryan and Deci’s (2000) *intrinsic and extrinsic motivation*, and the concept of *interest* (Hidi & Renninger, 2006; Krapp, 2002, 2005). The link between these concepts and the Eccles et al. model are described by Eccles and Wigfield (2002).

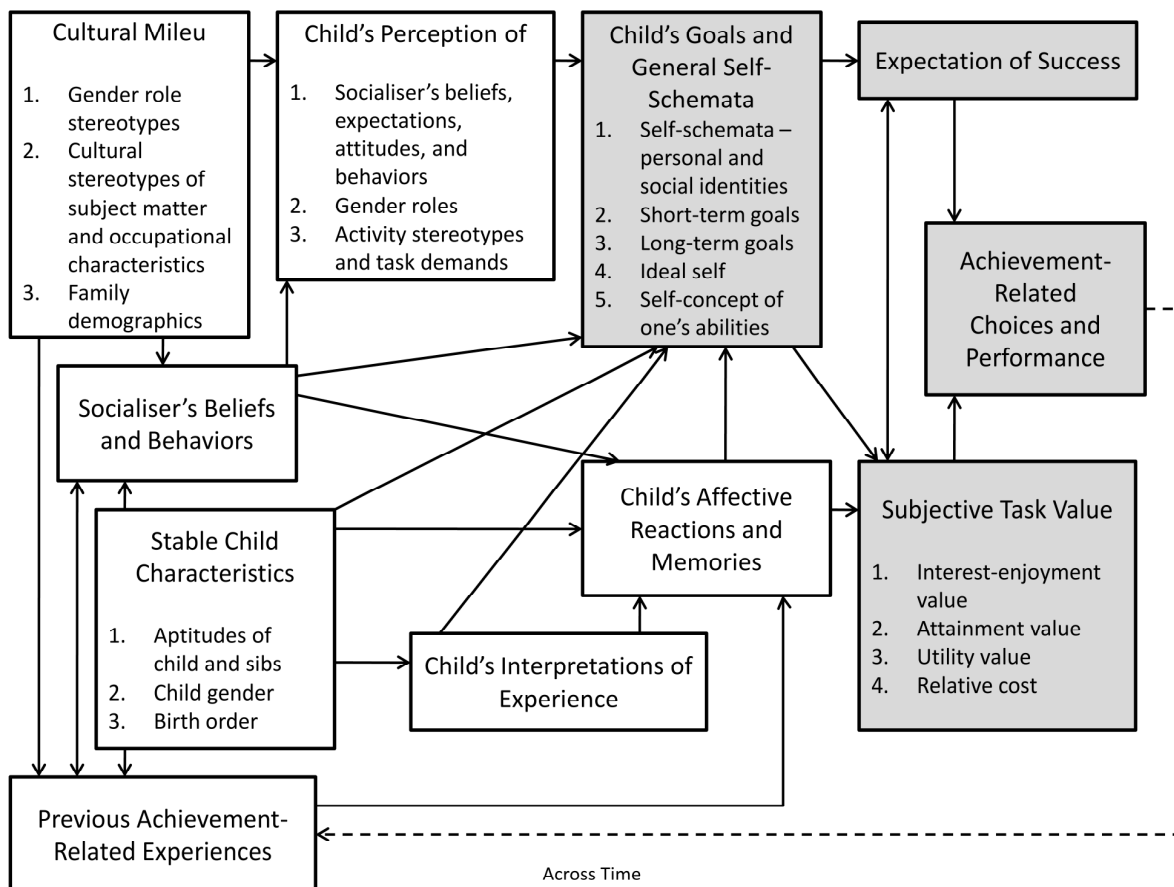


Figure 1: Eccles and Wigfield (2002) expectancy-value model of achievement-related choices. This article focuses most strongly on the concepts in the shaded boxes. Modified with permission

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Expectancy-value theory is a long-standing perspective on motivation (Wigfield & Eccles, 2000). The chief idea is that 'individuals' choice, persistence, and performance can be explained by their beliefs about how well they will do on the activity and the extent to which they value the activity' (ibid., p. 68). The motivation for an educational choice thus consists of two main aspects: the students' expectation of success and the value the students attribute to this particular option. The Eccles et al. model predicts that *expectation of success* and *subjective task value* directly influence achievement-related choices. Subjective task value consists of *interest-enjoyment value*, *attainment value*, *utility value*, and *relative cost*. The model assumes that expectation of success and subjective task value are positively related (Eccles & Wigfield, 2002), which implies that people tend to value what they believe they can do well and devalue what they do not master. People also expect a higher degree of success on tasks and subjects that have high value for them.

In the model, *identity* forms expectations and values, and affects achievement-related choices, such as a career choice (Eccles, 2009). According to Eccles and colleagues, students' *personal identity* includes self-image, values and goals, and the identity they think they may hold in the future. Students' *social or collective identities* are about how they see themselves in terms of social categories, and how they express membership to these categories through symbols and activities. *Gender identity* has also been thoroughly addressed by Eccles and colleagues (Eccles, 1994, 2007, 2009; Eccles, et al., 1999; Nagy, et al., 2008). Culture defines gender and the stereotypes related to jobs, subjects and activities. Young people use these stereotypes as tools in their identity work. They have their own perceptions of each stereotype, and they are influenced by parents, peers and other socialisers. The model contends that culture, through gender and gendered stereotypes, socialise young men and women differently. This suggests that they may develop different hierarchies of core personal values (Eccles, 2009; Eccles, et al., 1999), and value activities and future goals differently, because gender tends to suggest which activities go with which identity.

A few issues should be given some consideration when using the Eccles et al. model in studies of young people's STEM-related choices. These are not all necessarily limitations of the model, but features that may have implications for research questions, study design or interpretations of results. First, young people's educational choices are likely to be shaped in various complex ways *over time* (Cleaves, 2005; Holmegaard, Ulriksen, & Madsen, 2010; Vaughan, 2005). It will be valuable to complement research that concern young people's expectations of success and subjective values at one point with qualitative in-depth and longitudinal studies, to assess how expectations and subjective task values develop and affect choices over time. As illustrated by the dotted line in the model (see Figure 1), achievement-related choices and performance at one time affect later choices through the personal experiences they lead to. In addition, the cultural milieu that affects expectations and subjective task values (see Figure 1) is constantly changing. This can be a challenge if results obtained at one time are used to form, for example, recruitment initiatives after changes have occurred in the surrounding cultural milieu. However, this also offers explanations to how cultural changes may contribute to observed trends in STEM participation. For example, today's strong focus on environment and climate change is likely to increase students' interests in such issues, which according to the model may lead to increased enrolment in environment related studies. Such an increase is observed in, for example, the US (Vincent, 2009), the UK (Blumhof & Holmes, 2008), and Norway (Norwegian Universities and Colleges Admission Service [NUCAS],

NUCAS, 2007; 2010). Many countries also report increasing proportions of women among medical students and practitioners (Kilminster, Downes, Gough, Murdoch-Eaton, & Roberts, 2007), while engineering and physical sciences experience great gender imbalance (EU, 2009). Young women in general are more interested in health issues than technology (Tytler, Osborne, Williams, Tytler, & Clark, 2008). Also, a medical education and profession may be well suited to a female gender identity, thus giving medical studies a high *attainment value* to many women. The Eccles et al. model then suggests that more women would choose medicine than engineering – which is consistent with the observation that while the proportion of women in higher education in general, and in medicine in particular, has increased considerably in the later decades, the physical sciences and engineering have not experienced a corresponding increase.

Some STEM researchers may argue that social structures related to ethnicity and class are understated in the Eccles et al. model. However, although class and ethnicity are not listed explicitly in the model in Figure 1, they are present as parts of individuals' cultural milieu and their socialisers' beliefs and behaviours. It should be kept in mind, however, that mechanisms involved in decision-making may vary across cultural settings and subgroups, and that the model may need to be adjusted to fit conditions that differ significantly from the conditions in which it was developed (mainly the US), for example developing countries.

Another issue is that expectancy-value theories like the Eccles et al. model have been criticised for assuming that people consider all options, and that they have sufficient correct information on which to base decisions (Bandura, 1997). However, the term *subjective* task values implies that what matters is the individual's *subjective interpretation* of, for example, what a science course has to offer. Similarly, in the model, it is not the actual costs of the course that affect the choice to participate or not, but *the costs individuals believe to be involved*. This is true whether the individual is well-informed or has insufficient or even incorrect information.

Researchers should note that the components in the Eccles et al. model differ in character. While young people may evaluate the utility value of a study option by counting pros and cons, interest-enjoyment and attainment values are more related to emotions and affective experiences, and may not be evaluated in a similar manner. Holmegaard (2010) has studied the narratives young people create concerning their educational choices, and describes how "the gut feeling" is important in the pursuit of a "right choice". This might seem to be at odds with the Eccles et al. model, which may at first sight appear to portray a well-ordered and maybe rational decision-making scheme. However, we hypothesize that the "gut feeling" that students describe as important is likely to be composed of a number of components, for example, identity matching (Taconis & Kessels, 2009), affective as well as more rational subjective values, and conscious or subconscious self efficacy considerations. We believe that although these aspects are not fully articulated when students follow "the gut feeling", the components in the Eccles et al. model may nonetheless be strongly present as explanatory factors for their choices.

Finally, the Eccles et al. model does not address the role that mere chance and coincidence may play in people's educational choices. People sometimes express that their choice was largely coincidental (Schreiner, Henriksen, Sjaastad, Jensen, & Løken, 2010). They stumbled across a study, just happened to meet someone who inspired them, or ended up with what was a more or less random fourth or fifth choice in their applications. These students may be among the those who are less conscious of



the process, as mentioned above. But it could be that a real part of the variance observed in young people's STEM-related choices must be attributed to chance.

We believe that the Eccles et al. model offers several valuable insights to science and mathematics educators. It is comprehensive and founded on empirical evidence, and this article will demonstrate that it is suitable as a tool to help structure and interpret current research literature concerning young people's attitudes to, and participation in, STEM. When the above mentioned issues are taken into consideration, it can also guide future research and suggest ways forward to increase participation in STEM. The model's focus on both expectation of success and subjective task value is particularly pertinent. Expectations or efficacy-beliefs alone, though undoubtedly very influential, cannot fully explain young people's educational choices. Other strengths are the model's inclusion of social variables such as gender, cultural milieu, and socialisers, and its acknowledgement of the importance of identity.

### 1.5 The late modern zeitgeist

The causes of participation problems in STEM subjects and careers are many and complex. Since the decline in participation is a phenomenon occurring in many highly developed countries, but seldom in developing countries, it is conceivable that explanations may be found in patterns and processes in social life related to level of societal development. Schreiner and Sjøberg (2007), arguing from a sociological perspective, point to the pre-eminence that highly developed societies give to the individual and claim that modern young people tend to evaluate STEM education in terms of its contribution to their self-development. This article therefore discusses some characteristics of the late modern *zeitgeist* that may be relevant to understanding the STEM related educational choices made by young people.

Today's highly developed societies have evolved through various characteristic eras: from hunting and gathering, to agrarian society, to industrial society and finally to the current era. The periods are characterised by particular cultural and social patterns. Social change is not only a change of economic foundations, principal industries and prevailing skills and professions, but also a matter of cultural perceptions, social patterns and ways of thinking and understanding about oneself, one's surroundings, one's future and the world.

*Modernity* and *modernisation* are terms connected to cultural, economic and political developments in developed societies throughout the last two hundred years at least. Modernity is associated with the era of industrialisation and this discussion will be restricted to the most recent decades of the post-war period. Many terms have been used to classify the present day post-industrial period, including *high modernity*, *late modernity*, *reflexive modernity* (Giddens, 1991), *second modernity* (Beck, 1999), and *liquid modernity* (Bauman, 2001). This article uses the term *late modernity* (sometimes shortened here to *modernity*). Giddens and Beck described late modernity in the 1990s, but the period's characteristic traits are recognised also in more recent work (Bauman, 2008; Furlong & Cartmel, 2007). Some theorists, for example Jean Baudrillard and Jean-François Lyotard, argue that we have passed from the modern epoch into a new condition of *post-modernity* (Giddens, 1991). A post-modern society is described as highly pluralistic and diverse, with no universal principles and no common ideas or *grand narratives* (a concept proposed by Lyotard) that can direct the social development (ibid.). The post-modern conceptualisation of our society is contentious (Fornäs, 1995; Giddens, 2001), and many would argue that rather than an epochal shift, we are undergoing a

continuation of modernity into a late and accelerated stage: an ultra- or super-modernity. The epoch is recognised by a radicalisation, amplification and intensification of modernity (Beck, Giddens, & Lash, 1994; Fornäs, 1995; Miles, 2000). This article will not engage with the technicalities of this debate, but rather frame young peoples' educational choices within generally accepted aspects of the theories concerning late modern society.

Giddens describes the weakened roles of traditions and authorities in late modern society (Beck, et al., 1994). As people gain access to more information through media, education and other means, they develop an appreciation that so-called 'facts' can be temporary, incomplete and debatable. This leads people to question the credibility of the established traditions and 'truths' that are passed down from authorities and older generations. Consequently, authorities lose some trustworthiness, and religious leaders, scientists, politicians, teachers and parents have a weakened function in guiding young people in their beliefs, choices and actions. According to Ziehe and Stubenrauch (1993), the breakdown of traditions has led to *cultural liberation* of the individual. Cultural liberation means that the family background and the geographical background of the individual have less capacity to define a person's identity in terms of class, social status, ethnicity, sexuality, profession, geographical association, etc. The individual is less dependent on traditions, norms, and handed-down interpretations of who they are. Identity is no longer perceived as something that is given, but as something one chooses and develops. Young people in late modern societies tend to be more culturally, socially and geographically liberated than those in earlier generations. According to this view, young people in highly developed countries are largely free to choose their religion, social group, lifestyle values, education and profession.

These perspectives describe a late modern notion of free choice. Nevertheless, the idea is challenged by some sociologists and by empirical studies that point towards a still very pronounced social reproduction. Young people may have the *impression* that they have an almost infinite number of options and degrees of freedom, but youth studies find that the home background of young people will still influence their dispositions related to lifestyle, values and educational choices (Atkinson, 2008; Bourdieu, 1984, 1990; Furlong & Cartmel, 1997; Heggen, 2004; Krangle, 2004; Turmo, 2003). This means that in reality, they may not make their life choices as freely as it might seem to them. However, their *idea* that they choose freely makes these perspectives highly relevant for understanding their educational and career choices.

## **2 Looking at young people's relationship to STEM subjects and careers through the lens of the Eccles et al. model**

The research literature from science and mathematics education presented in this section is discussed in terms of the two constructs within the model that directly influence achievement-related choices: the subjective value of the school subject or university course for the individual, and the expectation of success in the subject or study. The discussion is structured around each of the four components of subjective value shown in Figure 1: interest-enjoyment value; attainment value; utility value; and relative cost, followed by a fifth section concerning students' expectation of success. For each component, three different aspects are considered: young people and STEM subjects and careers; young women and STEM subjects and careers, and how STEM choices can be understood in the context of the late modern zeitgeist. The description of the components in the

Eccles et al. model is based on various texts (Eccles, 1994; Eccles, et al., 1983; Eccles, et al., 1999; Eccles & Wigfield, 2002; Wigfield & Eccles, 2000).

## 2.1 Interest-enjoyment value

*Interest-enjoyment value* concerns how interested individuals are the subject in question, and the enjoyment they will feel when participating in it. Take for example the choice between two subjects in upper secondary school: advanced mathematics and economics. Students who are, for example, political activists are possibly quite interested in community economics. They may therefore enjoy economics and statistics more than calculus, and an economics course will have higher interest-enjoyment value for them than advanced mathematics. Interest-enjoyment value corresponds to *intrinsic motivation* (Ryan & Deci, 2000), Csikszentmihalyi's (2003) *flow*, and *interest* as described by Renninger and Hidi (2006), Krapp (2002) and Schiefele (1999).

### 2.1.1 The interest-enjoyment value of STEM subjects and careers for young people

Interest in, and enjoyment of, the subject were among the most frequently stated reasons for educational choice among all groups of respondents in the Future Track survey (Purcell et al., 2008), a large-scale, longitudinal survey following students from application to higher education until they get their first job. Some claim that interest in school science among young people in developed countries is low (OECD, 2008; Osborne, 2008; Tytler, 2007), and that it tends to decrease as students progress through school (Osborne, Simon, & Collins, 2003). Liking of mathematics has also been found to decline throughout school (Fredricks & Eccles, 2002; Wigfield, Eccles, Iver, Reuman, & Midgley, 1991). It is worth noting that interest in the topics *per se* may be a quite different matter from interest in school science and mathematics as experienced in the classroom. For instance, Häussler and Hoffmann (2000) distinguished between interest in the physics content and interest in aspects of school physics. They found that students' interest in physics as a school subject was less related to their interest in physics than to the students' self-esteem as being good achievers. Thus, for school physics, it appears that interest and expectation of success are positively related, in line with Eccles and Wigfield's (2002) claim. Lyons and Quinn (2010) found that declining science enrolments among Australian Year 11-students were likely to be due to school science's failure to engage students, but unlikely to be due to a decline in general interest in science among today's young people. There are also indications of a relatively high interest for science and technology topics in European populations in general (EU, 2005). The 2006 PISA study found that more than 90 % of 15-year-old students appreciated science in general and supported scientific enquiry, but only 57 % agreed that science is very relevant for them personally. The students also reported high levels of interest in the science topics examined by the PISA test, but only a minority saw themselves doing science in the future (OECD, 2007a).

Köller, Baumert and Schnabel (2001) found that mathematics interest among German 10<sup>th</sup> graders affected both the likelihood of choosing an advanced mathematics course and their achievement in upper secondary mathematics. The science education literature indicates that school science is often delivered in a conventional way which is very similar across countries (Angell, Guttersrud, Henriksen, & Isnes, 2004; Carlone, 2003; Lyons, 2006) and includes transmissive pedagogy, unengaging curricular content, and in the case of physics and chemistry, associated with difficulty. One topic that seems to engage young people is astronomy (Angell, et al., 2004; Osborne & Collins, 2001; Schreiner & Sjøberg, 2007). Angell et al. also reported that physics students found the more 'exotic' topics like relativity and quantum physics more appealing than applications-rich topics related to everyday life,

like electricity or friction. Regarding relativity, students (especially males) enjoyed the intriguing implications of the theory, and they (especially females) enjoyed having 'expertise' in a topic that sometimes emerged during everyday conversations. This social element of physics knowledge appeared especially important among women and helped them relate physics to the 'everyday world'. Along similar lines, Osborne and Collins (2001) found that British 16-year-olds (especially girls) emphasised the importance of science for explaining things to other people. Stokking (2000) found that most physics students in the Netherlands would like a stronger orientation of the subject towards the phenomena of daily life and of the instructional approaches towards active participation. Labudde et al. (2000) suggested that such changes would be effective for improving girls' experiences of physics and therefore might increase their likelihood of choosing a science career. However, the Relevance of Science Education (ROSE) survey investigated 15-year olds' interests in science in a range of countries, and found that not all every day contexts enhance interest. Neither girls nor boys are much interested in the weather, the sunset, how mountains and rivers develop and change, botany and farming, the work and life of scientists and how scientific knowledge develops, or in general everyday matters such as detergents and soaps, plants in the local area and how food is produced and conserved (Schreiner, 2006).

In short, school science appears to be unable to meet the students' personal interest in science-related topics. Lyons (2006) remarked that negative school science experiences may be a significant influence on students' enrolment deliberations, and moreover that school science for many students appears to offer few intrinsic incentives to continue. Barmby, Kind and Jones (2008) found that as British students progressed through lower secondary school, their experiences of science were more and increasingly related to school science and less to science in informal contexts. They suggested that it is therefore particularly important that in order to stimulate interest in pursuing science, school science needs to be an enjoyable experience for students. Braund and Reiss (2006) call for more out-of-school science learning, such as field trips, science centres and science museums. Häussler and Hoffmann (2000) claimed that physics as it is taught in the majority of physics courses does not take into account students' interests, and found that an interest-driven and context-rich physics curriculum was superior to the traditional physics curriculum and that it also resulted in an improved physics-related self-concept, particularly among girls.

### **2.1.2 The interest-enjoyment value of STEM subjects and careers for young women**

A number of interest studies in science education show that girls' and boys' interests are *different* (Cerini, Murray, & Reiss, 2003; Osborne & Collins, 2001; Scantlebury & Baker, 2007). On a general level, girls express stronger interest in issues to do with human health and well-being, whereas boys are more interested in things to do with e.g. technology and physics. Girls also appear to be generally less engaged by science (Tytler, et al., 2008). One likely reason why boys develop stronger interests in science than girls (particularly in the physical sciences), is that they have more childhood experiences involving science and technology (Hazari, Sadler, & Tai, 2008; Jones, Howe, & Rua, 2000; Sjøberg, 2000). Also, the decline in students' attitudes during secondary years has been found to be especially pronounced for girls (Barmby, et al., 2008).

The ROSE study found that the interests of girls differed markedly from those of boys in most countries. Whereas boys favoured 'dramatic' topics like explosions and technology, girls were more interested in how to take care of the body, how to care for animals, why we dream at night, and in aesthetic topics like the rainbow or questions about the paranormal (Schreiner, 2006). There appears to be a tendency for boys to be concerned with the subject itself, whereas girls are interested in

topics which may help them in their relations with themselves and other people. The preoccupation among young women with using their scientific insight in social settings was also noted by Angell et al. (2004) for physics students.

### 2.1.3 Interest-enjoyment value and the late modern zeitgeist

Beck and Beck-Gernsheim contend that

We live in an age in which the social order of national state, class, ethnicity and the traditional family is in decline. The ethic of individual self-fulfilment and achievement is the most powerful current in modern society (Beck & Beck-Gernsheim, 2002, p. 22).

Young people in late modern societies wish to develop their abilities, to fulfil themselves, and to live their lives to the fullest potential. As the existential meaning of life is to a lesser extent defined by religion or traditions, every person has to interpret this meaning for themselves (Furlong & Cartmel, 1997). To understand the culture of self-realisation, one may draw on classical psychological theories proposing that as some needs are satisfied, new and more sophisticated needs appear. The idea behind Abraham Maslow's hierarchy of needs (1968) is that humans are by nature searching creatures. Our needs will never be satiated, because as soon as one need is satisfied, we seek to satisfy other needs. The basic needs at the bottom of the pyramid are of a physiological character (to breathe, eat, sleep, etc.), while at the top lies the need for self-realisation. With an increasing level of modernisation and social welfare comes greater emphasis on subjective well-being, such as friends, leisure, good health, life satisfaction, ecology and free choice (Inglehart, 1997).

These perspectives are relevant for school and education, since educational institutions are seen as arenas for self-realisation and of fulfilling and developing personal talents and abilities. Late modern young people see their interests, their school subjects, their job plans, their friends, their views (on physics, mathematics and everything else), as part of their identity, of who they are (Beck, 1999; Giddens, 1991; Goffman, 1959). They wish to be occupied with something they can throw themselves into; something exciting and enriching. The discourse of the late modern era is characterised by words like *urge*, *desire* and *pleasure* rather than *patience*, *hard-work* and *obedience*. Students also expect passion and enjoyment in the learning situation, while monotony and tediousness are ill suited to their identity. *Independence*, *flexibility*, *communication* and *creativity* are key words describing their future job expectations (Illeris, Katznelson, Simonsen, & Ulriksen, 2002; Schreiner, et al., 2010; Ulriksen, 2003). An empirical study of Danish students' explanation for their educational choices found that the majority chose their subjects for 'existential individualistic' reasons – they wished to 'develop themselves', 'get wiser', and 'become deeply absorbed' (Simonsen & Ulriksen, 1998). Especially among young women, there is a pronounced emphasis on self-realisation, while young men are more inclined to accentuate issues related to material standards and achievements (Sjödén, 2001).

## 2.2 Attainment value

*Attainment value* refers to how well a subject or course fits with a person's identity. People want to confirm central aspects of their identity, and tend to place higher value on subjects that allow them to do so (Eccles, 2009). Eccles and colleagues draw on theories about self-concept and identity (see Markus & Wurf, 1987) to clarify this aspect of attainment value. Also part of attainment value is the importance of fulfilling personal needs through succeeding (Eccles, 1994). Success can make people

feel happy and proud of themselves, and it can be stimulating to overcome challenges. Identity – or *the self* – motivates the individual for action (Markus & Wurf, 1987). Individuals pondering whether or not to choose a STEM course may be motivated by imagining the *possible selves* that have completed this course. For instance, someone who wants to express high intelligence as part of their identity, may see an advanced mathematics course as having higher attainment value than an economics course, since the former is generally considered to be the more difficult. Of two possible selves, the *advanced mathematics self* is more consistent with the desired *intelligent self* than the *economics self*. Similarly it may be important to avoid subjects that are in conflict with a desired identity. If physics is perceived to be for ‘brainy’ and unpopular geeks, physics will have low attainment value for someone rejecting such an identity.

### 2.2.1 The attainment value of STEM subjects and careers for young people

Attainment value is closely linked to whether a person can identify positively with individuals associated with that subject area or profession. Literature from a range of countries has addressed the question of whether students see STEM subjects as worth pursuing and professionals in STEM fields as people with whom they can identify. Jenkins and Nelson (2005) and Bennett and Hogarth (2009) both reported that UK lower secondary students expressed a sense of science being important in general terms, although not having much appeal for individual students. Many students see school science as uninteresting and irrelevant to their lives (Tytler, et al., 2008), as authoritarian and abstract, and with little room for search for personal meaning (Sjøberg, 2003). In a combined English and American study, students reported that they found mathematics rigid, inflexible, and a subject that leaves no room for negotiation of meaning. Moreover, they did not see success in mathematics as relevant to their identity development, except in that it offered access to future education and careers (Boaler, William, & Zevenbergen, 2000). Masnick et al. (2010) found that American high school and college students considered scientific professions to be less creative and less people-oriented than other popular career choices. A large scale Australian study found that the most common reason given by 15 year-old students for not choosing any senior science courses was that they could not picture themselves as scientists (Lyons & Quinn, 2010).

Hannover and Kessels (2004) and Taconis and Kessels (2009) used self-to-prototype matching theory to investigate Dutch and German 9<sup>th</sup> grade students’ self-image and found that the students saw typical peers who preferred science subjects as being less attractive, creative and socially competent, but more intelligent and motivated, than peers who preferred foreign languages or economics. Thus, their image of the typical science student was that of a hard-working and intelligent, but rather boring and socially awkward person. Perhaps not surprisingly, most of the students in the survey saw themselves as less similar to the science prototype and more similar to the humanities prototype. Lapan, Shaughnessy and Boggs (1996) found that US students who described themselves as extroverted, were less likely to take additional mathematics classes in high school. Aikenhead (2006) states that ‘a school science identity or a good student identity may prove disastrous to students whose peers find their identities socially unacceptable (“It’s not cool”), causing these students to be unwilling to engage even in science discourse’.

Recently, science and mathematics educators have called for more attention to be given to the role that identity development plays in young people’s orientations towards science and mathematics in school (Aikenhead, 2006; Osborne, et al., 2009; Schreiner, 2006; Sfard & Prusak, 2005), and to the societal changes going on in most developed countries (Tytler, 2007). Brickhouse and colleagues have

studied how girls' identities are influenced by school science (2000; 2001), and argue that identity formation is essential to understanding science learning (2001). Kozoll and Osborne (2004) propose that a students' identity in science needs to be seen as part of their life world, of who they are, and what they want to become. Archer and colleagues (2010) describe how a science identity appeared unintelligible for some young people in their study, due to its dominant gender, race, and class configuration. Hazari and colleagues (2010) found that high school physics identities predicted physics career choice. Archer et al. (2007) linked young working-class students' urban identities to a resistance to higher education. However, there are students who are attracted to STEM subjects *because of* the traditional characteristics associated with them. Carlone (2004) studied girls' engagement in a physics classroom that focused on real-world physics applications, such as in sports and medicine. She discovered that some girls resisted the non-traditional meanings of science and scientists if they saw them as threatening to their 'good student' identities. In any case, it appears that students picture only a narrow range of STEM identities and, as Cleaves (2005) concluded, having a hazy picture of what a future science self would look like, is not conducive to choosing further studies in science.

### **2.2.2 The attainment value of STEM subjects and careers for young women**

Identities connected with some STEM subjects or courses are unattractive to many young women in particular. Eccles (2009) claims that attainment value is especially important when considering the impact gender has on the value students attach to a wide range of occupational options. We suggest that it is even more crucial in the case of decisions about STEM subjects. Aikenhead (2006, p. 117) states that 'coming to appreciate science requires an identity shift whereby students come to consider themselves as science friendly', and many careers in STEM are connected to gendered stereotypes. This suggests that young men and women attach quite different values to the identities associated with such careers. In her study of subject choices among young Americans, Eccles (2009) found that placing a high value on helping other people was a predictor for not choosing careers related to physical science or business and law. She also found that girls were less likely to enrol in advanced mathematics primarily because they found it less important, less useful and less enjoyable than did boys. The study by Lyons and Quinn (2010) found that Australian girls were significantly more likely than boys to attribute decisions not to take science to being unable to picture themselves as scientists. The authors recommend that efforts be made to better inform girls about the range of possibilities available to women in science careers.

Research has also identified that young women in science often lack role models (Miller, Blessing, & Schwartz, 2006; Osborne, et al., 2009), though Hazari et al. (2010) and others note that the effect of role models on young people's educational choices appears hard to document.

Buck, Clark, Leslie-Pelecky, Lu, and Cerda-Lizarraga (2008) found that girls' process in identifying a role model involved personal connections, and that their initial image of a scientist led them to believe they could not have such a connection with a scientist. What does appear to have an effect is personal connections with mentors or 'significant others' who knows the adolescents and is willing to help them clarify their goals, personal strengths and interests (Sjaastad, 2010). Aschbacher, Li and Roth (2010) also point to the effect students' socialisers have on their science identity and persistence in science. Baker and Leary (1995) found that 'the girls with the strongest commitment to scientific careers learned to love science through the love of a parent or grandparent involved in

science'. Hasse, Sinding and Trentemøller (2008) found that a majority of Danish female physicists in their sample had been inspired to pursue a physics career by their father.

Blickenstaff (2005) points to the lack of role models as one possible reason for women's underrepresentation in STEM, together with a science classroom pedagogy that favours male students, and an inherently masculine scientific epistemology. He claims that biology and life sciences are at the feminine end of the spectrum of sciences, with physics and engineering at the masculine end. Johnson (2007) found that minority group women were discouraged by science classes that presented science as decontextualised, and gender-, ethnicity- and race neutral. In the words of Osborne et al. (2009), 'both the context, purpose and implications matter for girls and any attempt to present a decontextualised, value-free notion of science will reduce their engagement.'

### 2.2.3 Attainment value and the late modern zeitgeist

Constructing and developing one's identity is, according to Illeris et al., at the heart of late-modern youth culture:

[...] And precisely this identity development can be seen as the essence or the driving force behind all the choices that young people today are plunged into, as the very central task of youth today (Illeris, et al., 2002, p. 26, our translation).

These authors argue that the traditional question 'What do you want to be when you grow up?' now addresses a more far-reaching issue than in previous generations. Today, the answer to this question should be seen less as a perception about a job or an income, and more as an answer to the question 'Who do you want to be when you grow up?' (ibid., p. 57, authors' emphasis, our translation). When young people choose an education or job, they simultaneously express important components of their identity. Education is seen as a means for self-actualisation and for fulfilling and developing personal talents and abilities. Young people wish to find a study they can be passionate about, something exciting and enriching (Illeris, et al., 2002; Simonsen & Ulriksen, 1998; Ulriksen, 2003). The processes characterising human development in highly developed societies imply that society accentuates the individual's freedom and independence. From the cultural liberation of the individual it follows that one's identity is no longer perceived as something that is handed out or given, but rather something one has to choose and develop by oneself (Côté, 1996; Giddens, 1991). It is up to each person to decide who one wants to be and in what way and direction one will develop oneself and one's life.

Across all epochs and cultures, the youth phase is commonly seen as a period in one's life which is particularly occupied with identity construction (Coleman & Hendry, 1999). Even though a person's identity is a relatively stable perception of 'who' one is, it is in continuous development. In the light of new knowledge and new experiences, people constantly reconsider and redevelop their self (Giddens, 1991). The US sociologist Erving Goffman sees social life as performances with agreed rules for behaviour. Based on his empirical analyses of human interaction, Goffman describes how every facet of people's public choices and behaviour, such as language, actions, values and beliefs, are tacit symbols or codes of social identities (Goffman, 1959). Choices are continuously made and remade on everyday matters, such as clothing, physical appearance, leisure activities, taste in music, sports, sexuality and beliefs (Giddens, 1991). Signs of what one *is not*, are just as important as signs of what one *is* (Frønes, 1998). Also in the school and classroom context, young people define and express



their identities through signs such as attainment, subject preferences, classroom and playground behaviour. All these signs can be seen as indicators of one's identity (Lyng, 2004).

## 2.3 Utility value

*Utility value* concerns how helpful an educational choice is in reaching *other* goals, such as career goals. Advanced mathematics often gives more credits than economics in applications to universities, which may give it higher utility value for some students. More short-term goals also include some utility value, for instance wanting to take the same course as a friend. Options that have utility value are extrinsically motivated (Ryan & Deci, 2000). Extrinsic motivation causes people to engage in activities to obtain a separate outcome. Physics may have high utility value for students who want to be admitted to medical studies, even if they have no interest in the subject.

### 2.3.1 The utility value of STEM subjects and careers for young people

Upper secondary STEM subjects often have a 'gate keeping' function for entry into prestigious higher education programmes such as medicine and engineering science. Some school systems also reward students with extra credits for STEM subjects. These subjects may therefore have utility value for many reasons: they can serve as qualifications for specific plans for higher education; they can raise a student's general qualification level for university admission, and they can help in keeping many options open as long as possible. It is therefore not surprising that utility for future careers often emerges as an important reason for choosing these subjects in upper secondary school (Angell, et al., 2004; Hutchinson, et al., 2009; Lie, Angell, & Rohatgi, 2010; Lyons, 2006; Miller, et al., 2006; Osborne & Collins, 2001). In their study of Year 13 students in New Zealand, Hipkins and Bolstad (2006) found that many students stayed in science to keep their options open. Similarly, Bøe (2010) found that many Norwegian students chose upper secondary science for its utility for university admission. However, in school systems where students are given a total score based on their average marks regardless of subjects, some may avoid STEM subjects, since they are considered difficult and may bring down their total average (OECD, 2008). Lyons and Quinn (2010) argue that the removal or weakening of extrinsic rewards traditionally given by Australian universities has contributed to lower participation in physical science subjects in schools.

In higher education, choosing a STEM field programme for its utility value would mean choosing it because it offers some kind of benefit apart from the intrinsic value or attainment value of the STEM course itself. A STEM course could, for example, be regarded as the best way to a secure job or a high income, or as necessary in order to get a job in a dynamic environment or with benefits such as travel. In most developed societies, however, STEM education programmes are unlikely to be regarded as an 'easy' way to good jobs or other benefits, because of their perceived high cost (see below). Moreover, for the majority of STEM-educated professionals, the prospects for high salaries are not much greater than for most other higher education courses of the same length, and certainly lower than for professions within finance and commerce. In a recent study of Norwegian first-year university STEM and non-STEM students (Schreiner, et al., 2010), the respondents rated a range of aspects of a future profession on a 4-point scale from 'not important' to 'very important'. It appeared that most students in all education courses rated aspects relating to self-development highest, whereas utility values such as salary and job safety were rated somewhat lower.

### 2.3.2 The utility value of STEM subjects and careers for young women

In many countries, young women are more likely than young men to attend higher performing, academically oriented tracks and schools (OECD, 2007a). This gives reason to suspect that young women make more instrumental educational choices than young men, and therefore rely more heavily on the utility value of post-compulsory STEM subjects. Miller and colleagues (2006) found that girls often planned science majors mainly because they needed it to enter health professions such as medicine. In a UK study, Bennett and Hogarth (2009) saw that among students who viewed chemistry positively, more girls than boys did so for career reasons. They pointed out that ‘subject “hardness” is more likely to be tolerated if it has the potential utility for future jobs’ (ibid., p. 1987). Hazari et al. (2010) use the term ‘outcome expectations’ for values that students seek in a future occupation, such as high wages, people-oriented work, etc., and they point out that there are great gender differences in these values. In their US study, boys were more inclined than girls to want jobs where they control others, jobs that are easy, make them famous, and give them high pay and status. On the other hand, girls were more inclined than boys to want to help others. Thus, given the image of science and scientists described above, young women are less likely than men to see many STEM careers paths as the best way to reach their goals.

### 2.3.3 Utility value and the late modern zeitgeist

Building a late modern identity is a *reflexive* project. It happens in constant negotiation with a rapidly changing society, filled to the brim with information, choices and trends (Giddens, 1991). To ensure that educational choices fit this project, young people are likely to want a lot of helpful information and as many open options as possible. Upper secondary STEM subjects are useful in this sense, because they often award students with extra credit and qualifications that make them eligible for many different university studies. Choosing not to continue with post-secondary STEM subjects may have an opposite effect, closing doors to further studies in many fields. Late modern young people are likely to find utility value in subjects that help their identity project, for example by ensuring admission to a university study they believe to be interesting and self-realising, or by keeping all options open until the interesting and self-realising career choice reveals itself. One may also expect late modern young people to value educational choices that lead to secure and well-paid jobs. Such jobs allow for subjective well-being, which is emphasised in modern societies (Inglehart, 1997), and may function as a safety-net against modern risks such as unemployment in an unpredictable global market (Beck, 1999). The persistent calls for more people in STEM suggest that a STEM career is a safe choice. However, the large costs that come with the choice, in terms of difficulty and many years of study, make it unlikely that young people seeking a fast track to well-paid, secure jobs will choose STEM over other career paths that offer faster ways to a high salary. It is also possible that stereotypes associated with people who choose STEM subjects and careers, alienate students who not only want a secure, well-paid job, but also a good social work environment (IET, 2008).

## 2.4 Relative cost

*Relative cost* refers to the negative aspects of one educational choice relative to other options. It could for example be the time and effort that is required to do well in advanced mathematics compared to economics. It could be the fear of failing advanced mathematics, or the fear of disappointing one’s parents. Relative cost also includes lost opportunities from choosing one subject over another, or having to put up with negative stereotypes associated with a subject or profession.

### 2.4.1 The relative cost of STEM subjects and careers for young people

Physical science and mathematics subjects on all levels are generally perceived to have higher costs than most other subjects. This is largely related to their reputation as being difficult and work-intensive (see subsection on expectation of success). For students who choose STEM subjects in upper secondary school primarily for utility reasons (to get into medical school, for instance), the cost may also be considerable in terms of having to put up with subject matter they find uninteresting, unattractive and ill matched to their identities. For some students, science and mathematics subjects also carry costs in terms of math anxiety, that may affect choices and performance (Ashcraft, 2002; Hembree, 1990). However, choosing these subjects tends to reduce the potential costs of lost opportunities due to 'wrong' choices, since they keep many options open for further studies (see discussion under Utility Value).

### 2.4.2 The relative cost of STEM subjects and careers for young women

Young women appear to perceive the costs of pursuing STEM careers to be particularly high (Angell, et al., 2004; Carlone, 2003; Frome, Alfeld, Eccles, & Barber, 2006; OECD, 2008; Warrington & Younger, 2000). It may be that girls are generally more afraid than boys of failing in STEM subjects and courses. For example, Norwegian girls who have chosen upper-secondary science worry more than boys about not being clever enough to master the subjects (Bøe, 2009). Girls are also often in the minority in physics or advanced mathematics classrooms, a circumstance which some of them would regard as a cost. In addition, the pedagogy in many science classes has been found to favour male students and to use inherently masculine scientific epistemology (Blickenstaff, 2005), which involves extra costs for girls.

### 2.4.3 Relative cost and the late modern zeitgeist

The theory of the *global risk society* was proposed by Beck (1999), who sees risks as unforeseeable future accidents or disasters caused by present-day choices. These are among the unpleasant outcomes of modernisation. In the context of environmental problems, Beck describes how social and technological development, along with globalisation, has led to unpredicted and unintended side-effects. This theory of the risk society was developed further, to include the personal lifeworld of the individual (Beck & Beck-Gernsheim, 2002). For example, people in late modern societies are aware that by choosing an education, a career, a partner, a hobby or a lifestyle, one exposes oneself to risks. Things can go awry and the choice may turn out to be the wrong one. The choices one makes may be perceived to be critical, or even fatal. In some contexts, educational failure, unemployment and poverty may all be regarded as the result of wrong choices. Consequently, people's actions and choices may be guided by risk evaluations, and by steering clear of danger.

Late modern young people can benefit from the opportunity to form lives which correspond with their interests and values. But this freedom carries some challenges, since traditions and norms have to some extent functioned as safe and supporting frameworks. Cultural liberation creates freedom to choose, but also the *obligation* to choose, and young people must make their choices with less guidance from traditions and authorities. Furthermore, when they have made their choices, they are themselves responsible for the outcome, they have only themselves to blame, and must themselves handle the consequences if something goes wrong (Furlong & Cartmel, 1997). For example, an educational choice represents risks, as it may lead to drop-out or failure by not fulfilling expectations, or by being too demanding and hard to get through. Modern young people tend not to explain this unhappy situation in terms of religion, destiny, nature, inheritance, limitations of social class or lack

of options, but by their personal failure. The late modern notion of free choice gives them the full responsibility, even if their problems are actually rooted in social constraints (Furlong & Cartmel, 2007). Young people in Beck's individualised risk society (1999; 2002) are likely to negotiate their educational choices against the risks and other relative costs they entail.

## 2.5 Expectation of success

Students presented with various educational options will evaluate their chances of succeeding with each of them. For example, what students see as success in advanced mathematics and economics, depends on their self-images in mathematics and economics. Achieving a mark just above average in mathematics may be seen as a success if they see themselves as an average mathematics student, but a failure if they consider themselves to be very good mathematics students. Expectation of success also includes the student's estimations of how difficult the subjects are. If they regard advanced mathematics as more difficult than economics, they may characterise a slightly above average mark in advanced mathematics as a big success, while an equal level of success in economics would require a top mark. Eccles and Wigfield (2002, p. 119) define *expectation of success* as 'individuals' beliefs about how well they will do on upcoming tasks'. They distinguish between expectation of success in *specific upcoming tasks* and beliefs about *abilities* in broader fields. However, they have found that children and adolescents do not distinguish between these two, and that the two concepts cannot be empirically separated (Eccles & Wigfield, 2002). They also state that expectation of success is measured in a manner similar to Bandura's *self-efficacy beliefs* (see e.g. Bandura, 1997; Bandura, Barbaranelli, Caprara, & Pastorelli, 2001). Eccles (1994) argues that people's hierarchies of efficacy in different subjects matter more than the actual level of efficacy. The crucial point is not, for instance, whether girls feel as efficacious in mathematics as boys, but whether or not girls and boys feel less efficacious in mathematics than in other subjects.

### 2.5.1 Young people's expectation of success in STEM subjects and careers

Physical science and mathematics subjects have a reputation as particularly difficult and demanding (Angell, et al., 2004; Carlone, 2003; Osborne & Collins, 2001; Tytler, et al., 2008), which alone is likely to reduce students' expectation of success in these subjects. Indeed, even gifted students and students who are high achievers in science subjects have been found to have lower expectation of success in these subjects than in most others (Lyons, 2006). Bennett and Hogarth (2009) found that physics was seen as hard; students felt they could get better marks in another subject. There is evidence to indicate that it is in fact more difficult for students to achieve high marks in the physical sciences than in other subjects (Coe, Searle, Barmby, Jones, & Higgins, 2008). This may have a negative effect on participation in STEM subjects, since an early sense of mastery (or lack thereof) shape expectation of success (Eccles & Wigfield, 2002). For example, Shapka, Domene and Keating (2008) found that early mathematics achievement works as a filter for Canadian students' educational and occupational aspirations. Students' self-perception and expectation of success in mathematics and science are also shaped by parents and teachers, who thereby also influence future educational choices (Hazari, et al., 2010).

### 2.5.2 Young women's expectation of success in STEM subjects and careers

Young women have been found to have lower self-efficacy in science and mathematics than young men (Barnes, McInerney, & Marsh, 2005; Cavallo, Rozman, & Potter, 2004; Lloyd, Walsh, & Yailagh, 2005; Lyons, 2006; Preckel, Goetz, Pekrun, & Kleine, 2008; Simpkins, et al., 2006), and low expectation of success appears to reduce their willingness to choose STEM subjects and STEM

careers in particular. In their study of American college students, Lapan, Shaughnessy and Boggs (1996) found that girls had less faith than boys that they could perform mathematics and science tasks successfully, and they expressed less vocational interest in mathematics than boys did. Häussler and Hoffmann (2000) found that for German students, boys' physics-related self concept was higher than their general school-related self concept, whereas the opposite was true for girls. The Future Track survey report describes a "confidence gap" in their report on first-year students: Women rate themselves lower than men in numeracy and computer literacy (Purcell, et al., 2008).

Zeldin et al. (2008) and Zeldin and Pajares (2000) found differences in the ways young women and men develop their self efficacy related to science and mathematics education and STEM careers: Whereas men's self efficacy arises most strongly from actual (perceived) achievement in tasks, women rely more heavily on interaction with others to build their self efficacy. There are also stereotype threats related to girls' and women's abilities in some STEM areas. In their American study of how stereotype threats interfere with women's performance on a mathematics test, Quinn and Spencer (2001) found that women performed better if the stereotype threat was reduced, that is, if they were told that men and women have proved to score equally well on the test. However, Dar-Nimrod and Heine (2006) showed that the stereotype threat had much less influence if the stereotype was presented as a result of different experiences rather than genetics. Also worth noting in this context is that girls appear to have other criteria than do boys for feeling that they understand the subject matter. Girls tend to believe they understand a concept only if they can put it into a broader world view, whereas boys appear to view physics concepts as valuable in themselves, and are satisfied if there is internal coherence among the physics concepts learned (Stadler, Duit, & Benke, 2000). Osborne and Collins (2001) found that girls expressed a desire to know *why* things happened in science rather than learning only *what* happened. This adds to the impression that many girls feel alienated by decontextualised presentations of science (Osborne, et al., 2009).

### 2.5.3 Expectation of success and the late modern zeitgeist

Individualisation means that each person has a unique character with special potentials that may or may not be fulfilled (Frønes & Brusdal, 2001). Young people in late modern societies wish to develop their abilities, to fulfil themselves, and to live their lives to the fullest potential. What they regard as their abilities and potential will influence their expectation of success in various activities. Their need to live up to their abilities and realise their potential, makes expectation of success particularly important. Young people's expectation of success in STEM subjects are challenged by the subjects' reputation as particularly difficult and demanding, which causes some students to shy away from these subjects. For late modern students, who feel responsible for the outcome of their free choices (Furlong & Cartmel, 1997), it may therefore be difficult to develop an expectation of success that is strong enough to outweigh the potential costs related to a failure and lost opportunities.

## 3 Conclusions and implications

This article's review of research literature, has presented evidence that young people's interest in school science and mathematics is relatively low, and tends to decline as they progress through school. The subjects are often characterised as having transmissive pedagogy, and unengaging, decontextualised content. For science, however, the disenchantment is greatest with *school* science. Students often show more interest in science topics *per se*. Students also regard science and mathematics as important in general, but less so for them personally. They struggle to identify with

STEM culture and with STEM professionals, and often find them ill suited to their identity. Many students tend to choose post-compulsory STEM subjects for instrumental reasons: for example to gain admission to a preferred university or keep their options open. Promises of a good job market and high salaries also motivate STEM choice, but STEM subjects and studies do not appear to offer the easiest paths to money and job security due to their reputation as costly in terms of difficulty and work load. This perception of difficulty also affects students' expectation of success in these subjects, which is generally lower than their expectation of success in other school subjects.

The literature also revealed gender differences in young people's considerations within all the important elements of the Eccles et al. model. Girls tend to have lower expectation of success and perceive a higher cost associated with studying science and mathematics. They identify less closely than boys with the disciplines and the professionals associated with these subjects and have different interests and different expectations for their understanding within the subjects. Finally, girls are less inclined to regard STEM as a means of attaining extrinsic goals and expectations than are boys.

### **3.1 Implications for improving participation in STEM subjects and careers**

This article has demonstrated that the model developed by Eccles et al. provides a very useful lens through which to examine, structure and interpret the research literature concerning young people's relationships to and decisions about science and mathematics. The perspectives gained from this process, aided by valuable contributions from sociological theories of late modernity, constitute a strong evidence-based foundation for considering STEM participation issues. The following discussion suggests how students' expectations of success and the interest-enjoyment value, attainment value, and utility value of STEM subjects and studies may be increased, and their perceived costs reduced, in order to reduce the impediments to increased participation in STEM subjects and careers.

#### **3.1.1 Interest-enjoyment value**

There is evidently a challenge in keeping students interested in school science and mathematics as they progress through school and approach decision points about post-compulsory participation. The common characterisation of school science and mathematics pedagogy as dull, decontextualised and transmissive are especially alarming, considering that interest and personal relevance are very important for late modern young people. Teaching styles and textbooks that try to counteract this impression may be helpful in this respect, for example by taking advantage of the interest students have in science topics, which appears to be higher than their interest in traditional school science. The literature also suggests that interest and enjoyment in STEM subjects can be increased if subject matter is more closely linked to science in society contexts and to activities that actually reflect the way STEM professionals work. The tendency for girls to be less interested in science than boys, and for girls and boys to be interested in different topics and contexts cannot be overlooked. Relating subject matter to social issues of current interest may be especially beneficial for girls, who to a greater extent than boys want their scientific insight to benefit themselves and other people. For example, they may find STEM subjects more interesting if the applications for these subjects to health care and environmental concerns were more apparent to them.

#### **3.1.2 Attainment value**

To be more attractive to contemporary young people, STEM subjects and studies must be taught and presented in a way that acknowledges their identities. The literature suggests that many students

feel alienated by what they believe are STEM subject identities, and struggle to picture themselves in STEM careers. It may be helpful in this respect to introduce them to a broader range of STEM career identities, and to correct and broaden the range of stereotypes related to STEM education and careers. In terms of an education programme, this may entail new thinking about both course profiles and composition. For example, a Masters programme in environmental engineering could introduce a course in applied technology for renewable energy sources in the first year, instead of after two years of groundwork mathematics and chemistry. STEM industries may be able to add to students' knowledge about possible STEM identities by making the opportunities they offer more visible to students. Nanotechnology, for example, has possible applications both in making boats go faster through water, and in making nerves grow to cure paralysis. These are two research areas that may attract quite different student identities. Typical late modern girls may find it easier to picture themselves in STEM subjects and careers if they know more about the many opportunities STEM careers offer for helping other people. Role models are often promoted as influential sources of advice and information about various career possibilities. They may come in the shape of likeable tutors from university mathematics departments, enthusiastic and knowledgeable media commentators on STEM issues, or fictional forensic crime experts in TV shows.

One approach shown to be effective is personal meetings with a mentor or 'significant other'. This is particularly important for young women, who rely more than young men on personal relationships and advice. Female role models that challenge STEM stereotypes are particularly valuable, since young women tend to find traditional stereotypes less attractive than do men. Moreover, a possible strategy might be to make parents, teachers and others with whom young people relate aware of the important role they can play in helping young people make their educational choices, and to alert these 'significant others' to how STEM subjects may actually accommodate a wide variety of job preferences and people with a range of values and aims. Teachers are in a unique position to communicate such information to students.

### **3.1.3 Utility value**

In many educational systems, post-compulsory STEM subjects offer extra credits and qualifications that facilitate admission to university studies. The literature suggests that such extrinsic rewards do attract many students to these subjects in school, and that removing these rewards contributes to lower participation rates. It is therefore possible to exploit this utility value to encourage more students into post-compulsory STEM subjects. The literature suggests that students are particularly eager to keep many options open. They may therefore be tempted to choose STEM subjects if they knew more about the range of opportunities that are open to students completing upper secondary school with the appropriate courses. Having many options open is attractive to late modern young people because it increases their chances of finding a self-realising career that fits their identity. It also reduces the risk of failure in their identity development project.

As well as removing barriers to the initial choice of STEM subjects and courses, consideration must be given to ensuring that students are not faced with additional hurdles to STEM careers. The challenge is then to provide students in STEM subjects and courses with sound and authentic reasons to pursue STEM career paths. These motivational aspects can be integrated into course materials and experiences, for example, introductions to a variety of attractive STEM career options.

### 3.1.4 Relative cost

In the literature we find that STEM subjects, studies and careers are associated with significant personal costs. This suggests that initiatives to increase participation could aim at reducing young people's perception of these costs relative to the benefits that STEM subjects and studies offer. It may not be feasible or even desirable to change the STEM subjects' reputation as difficult and demanding compared to most other subjects. However, it seems possible to make those characteristics less costly and reduce fear of failure in STEM subjects. One approach is to communicate that STEM subjects are challenging, but that this very fact contributes to making them attractive to pursue – in much the same way as sports-interested youth may be motivated to exercise in order to beat their own (or someone else's) previous records. Another approach may be to initiate study groups, tutoring and homework support programmes in order to reduce students' fear of failure. Such programmes can also increase expectation of success, interest-enjoyment, and attainment value by using tutors who can build confidence, present subject matter in interesting and enjoyable ways, and function as role models who help students picture themselves in STEM careers. Role models may also help in reducing another cost identified in the literature: the geek-label and other negative characteristics associated with students choosing STEM. For late modern young people, it costs to choose a subject that carries an identity in conflict with one's own. Special attention may be given to reduce the costs for young women by removing the stereotype threat that they are less capable than men in STEM subjects, and adjusting the subjects' reputations as objective, values-free and masculine in nature. It also appears that STEM education programmes and workplaces are likely to recruit more young women if they encourage female friendly work environments, and ensure careers can be combined with family life. On a final note, it is important to reduce the described costs *relative* to the interest-enjoyment, attainment and utility value. The total influence of expectation of success *and* subjective values determines whether or not a student chooses a subject. Reducing the costs is a clear aim for efforts to increase participation, but the remaining costs may be seen as worthwhile in view of the increased subjective value.

### 3.1.5 Expectation of success

It is an obvious challenge that many students have low expectations of success in STEM subjects, and that it is often lower than their expectation of success in school more generally. Young women have been found to develop efficacy more through social interaction and less through task achievement than young men (Zeldin, et al., 2008). Study groups and organised homework help may therefore increase young women's expectations of success in particular. It could also be that the traditional focus on 'right or wrong' answers makes expectation of success in STEM subjects typically 'either/or', and that this benefits young men's efficacy development more than young women's. Teaching and assessment methods that open for experiences of mastery during activities, and not only when the correct answer is obtained, may encourage efficacy development for both genders. It is alarming that stereotype threats suggesting women are less talented in mathematics than men, actually lead to poorer performance (Quinn & Spencer, 2001). This stereotype is unfounded and should be removed once and for all. Finally, the positive relationship between expectation of success and subjective values should be acknowledged. Allowing students to work with subject matter that interests them and is important to them may increase their expectation of success.

### 3.1.6 Even more pressure on teachers?

Our recommendations and those of others (for example Hazari, et al., 2010; Institution of Engineering and Technology [IET], 2008) suggest that teachers are key actors in the efforts to



increase participation in STEM education and careers. However, teachers struggle with demanding schedules, large student groups and high piles of tests and reports to grade. There is not much time left over for initiating new approaches for increased participation. Any new teaching strategies or materials should therefore be easily accessible, require little additional preparation, and be straightforward to incorporate into the curriculum. To make full use of the potential influence teachers have on students' choices, their everyday work structures must allow it.

### 3.2 Implications for research

This article suggests that future research on increasing participation in STEM subjects and careers may benefit from using the Eccles et al. model as a framework, and that the presented perspectives from sociological theories on late modernity and identity development offer helpful additional insight in such research. Further it implies that the science and mathematics education literature reviewed here provides a good starting points for generating research questions and hypotheses.

The discussion above recommended ways of increasing STEM participation by seeing research findings through the lens of a model for educational choice. However, to develop the most fruitful approaches, research must identify what works and how. At present, not much thorough research has been done on the effects of STEM recruitment initiatives (Jensen & Henriksen, 2010). It would, for example, be valuable to see studies on whether role models can help students picture themselves in STEM careers. Despite their expectations, Hazari et al. (2010) could not conclude whether female scientist role models informed young women's physics identity. Studies concerning how much young people (in different age groups and educational levels) know about the wide range of possible STEM applications and careers, would also contribute to the discussion. As another example, the effects of tutor programmes and study groups should be evaluated as results could address the questions of whether they encourage students to choose STEM subjects and ultimately STEM careers, whether they help develop expectations of success, or deal with fear of failure, or enhance student interest.

This article argues that young people in highly developed countries are affected by the late modern zeitgeist when they make STEM-related choices. It is hoped that future studies will further explore this phenomenon. Pertinent research questions could include: how important is it for young people to realise themselves through an educational choice? To what extent is an upper secondary subject choice an identity choice? How do young people evaluate the risks and benefits involved in choosing STEM subjects and careers?

Some specific issues related to gender differences and young women's choices have been outlined in this article. These issues should also be addressed specifically by research. For example, can better information about applications in health care and environmental protection attract more young women to physics? How can stereotype threats be battled in classrooms and textbooks? Science and mathematics education are likely to benefit from more knowledge about the interplay of expectation of success and subjective values involved in students' decision-making. We might therefore ask how students weigh these components up against each other. Are some subjective values more influential than others? Are there hierarchies of expectations and values that differ characteristically between groups of young people: students in different countries, from different social backgrounds, or of different genders or ethnicity? It must not be forgotten that initiatives meant to increase the participation of young women may work equally well to recruit and retain more diverse groups of young men (Labudde, et al., 2000). Further, the diversity of outlooks among young women *and* men

is extensive, so gender in itself is a poor predictor of, say, interest in physics or expectation of success in mathematics.

#### **4 Concluding remarks**

This article argued the need for not only a larger number, but a larger diversity of people in STEM fields. It then presented the Eccles et al. model of achievement-related choices and used it as a theoretical lens through which to examine and structure empirical and theoretical contributions from science and mathematics education research in order to understand young people's educational choices. The article proceeded to discuss the implications of these insights for STEM recruitment interventions and for future research.

Many of the initiatives and directions for further research which have been suggested in this article are by no means new. However, since the level of young people's participation in STEM is still a pressing issue, science and mathematics educators, researchers and other stakeholders need to continue to focus on exploring solutions and to implement them and evaluate what works in practice. The conclusions and suggestions presented in this article can contribute to structuring future research and development related to improving STEM participation. We believe the framework of the Eccles et al. expectancy-value model, with additional perspectives from sociological theories of late modernity, is not only useful for understanding young people's participation in STEM, but for designing and evaluating initiatives.

In this article, we have tried to contribute to a structured and empirically founded understanding of the considerations which guide young people in their decisions to pursue (or not to pursue) a STEM education and career. Braced with such understanding, we have proposed measures that may increase the diversity of personalities that may feel attracted to STEM so that the future workforce within these fields will not only be greater in numbers and more even in gender distribution, but will generally include a greater multitude and variety of outlooks, experiences and aims. Such diversity may spark new ways of thinking and new applications of STEM knowledge, for the benefit of the individual and for society. Moreover, inviting new groups of young people into STEM educations and careers may give them opportunities for fulfilling and self-realising experiences, and help them pursue their goals for meaningful lives and careers.

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